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PREDATION, MERGERS AND INCOMPLETE INFORMATION

Garth Saloner\*

Number 383

April 1985  
Preliminary

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## I. Introduction

This paper presents a model of rational predation based on asymmetric information. We show that the presence of asymmetric information substantially alters the conclusions that should be drawn about predatory pricing. First, even when friendly takeovers are anticipated (and permitted), predation may occur. Second, actions that would be judged to be predatory under the leading formulations of legal rules for such practices, and hence that would be punishable under Section 2 of the Sherman Act if those rules were applied, may actually be welfare enhancing.

Predatory pricing refers to price-cutting for the purpose of driving existing rivals out of an industry or to deter potential rivals from entering an industry. These two objectives are related since aggressive pricing that results in the exit of an existing firm may also deter other potential rivals from entering if they fear the same fate. Nonetheless, the theoretical literature has developed distinct treatments of these two objectives.

The first branch, the limit-pricing literature, focuses on the case of potential entry. In the earliest limit-pricing models, the potential entrants were assumed to believe that the established firm would maintain its pre-entry output after entry occurred (Sylos-Labini (1970), Modigliani (1958)). Later models assume merely that entry is more likely (Kamien and Schwartz (1971)) or occurs at a faster rate (Gaskins (1971)) the higher is the pre-entry price. In all of these models the incumbent has an incentive to increase its pre-entry output (reduce the pre-entry price) since the loss in current profits is compensated by the reduction in entry and the accompanying reduction in competitive pressure later on. More recently, Milgrom and Roberts (1982a) developed a model in which the beliefs of the entrants about the nature of post entry competition are endogenous. They

consider a monopolist facing a single potential entrant with neither firm fully informed about the other's costs. If the entrant's profits are higher if it enters against a high-cost established firm than if it enters against a low-cost established firm, the monopolist may attempt to signal that it has a low cost structure in the hope of deterring entry.<sup>1</sup>

The second branch, the price-cutting literature, focuses on the case of existing rivals. These models typically involve price-cutting by the predator to levels that are unprofitable for the rival, driving the rival out of the industry. Following the exit of the rival the predator raises the price and reaps monopoly profits. For such a strategy to be successful several conditions must be satisfied<sup>2</sup>: (i) the predator must be capable of driving the rival out of the industry, (ii) there must be a barrier to the reentry of the rival once the predator raises the prices, and (iii) there must be a barrier to the entry of new rivals.

The theoretical explanations of predatory price-cutting have been criticized on several grounds. First, the ability of the predator to drive the rival out of the industry is usually either merely assumed or else is based on asymmetric financial strength of the predator and rival (See Telser (1965) and Benoit (1981) for discussions of "deep pockets"). The requirement of such asymmetries reduces the scope of the models. Second, McGee (1958) argues that predatory price cutting is not a profitable strategy since "outright purchase [of the rival firm] is both cheaper and more reliable". The same argument was echoed by Telser (1965): "Either some form of

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<sup>1</sup>This model has been extended to allow for exogenous uncertainty, (Matthews and Mirman (1983)), exogenous uncertainty and a multiperiod framework (Saloner (1982)), and incomplete information about common costs (Harrington (1984)).

<sup>2</sup>See Ordover and Willig (1981) and Areeda and Turner (1975) for discussions of these conditions.

collusion or a merger of the competitors would seem preferable to any possible outcome of economic predation". The essential idea behind those arguments is that since predation is costly, the firms ought to realize that a Pareto improvement (in the form of a merger) exists and ought to be negotiated.

Yamey (1972) has pointed out that McGee's argument omits several important considerations. One such consideration that has recently been the subject of several fine contributions is expressed by Yamey as follows: "The aggressor will be looking beyond the immediate problem of dealing with its present rival. Alternative strategies for dealing with that rival may have different effects on the flow of future rivals" (p. 131). In their influential papers Kreps and Wilson (1982) and Milgrom and Roberts (1982b) have studied the creation and importance of a firm's "reputation for predatory actions". They study (primarily) finitely-repeated games in which an established firm faces the threat of sequential potential entry into a number of its markets. They show that if it is possible that the established firm is of a "type" that in fact favors a predatory response to entry, that this possibility may induce the firm to act as if it favors such a response early on whether it is in fact the "type" that favors a predatory response or not. In this way the firm alters the perceptions of future rivals about the likelihood of a predatory response to entry (i.e. it maintains a reputation for being "tough") and reduces the temptation of later rivals to enter.

This paper develops a simpler motive for predation, one that does not rely on the existence of a sequence of potential entrants. As with the reputation models, however, it also rests on the presence of incomplete information. Indeed the model is most closely related to the Milgrom-Roberts limit-pricing model.

We study the incentive for predation within the framework of a three-stage game. In the first stage two incumbent firms are involved in a Cournot game with one-sided incomplete information. In particular, one of the firms, the "rival" is uncertain what the costs of the other, the "predator", are. We study the simple case where the costs are of one of only two possible types, "high" or "low". As in the Cournot model outputs are chosen simultaneously<sup>3</sup>. At the end of the first stage the rival revises its beliefs as to the type of predator it is facing (on the basis of the observed output of the predator) and the firms enter into negotiations about a possible takeover of the rival by the predator. This bargaining constitutes the second stage. If the takeover does not occur the firms once more engage in Cournot competition with one-sided incomplete information. The outcome here will depend on the beliefs of the rival about the costs of the predator. Further these beliefs may be influenced both by the first-stage and second-stage actions. The solution concept is that of Bayesian Perfect Nash equilibrium.

As is typical for games of this kind, we consider the final stage first. The Cournot game with incomplete information analyzed here is of independent interest. For example, in the Milgrom-Roberts style limit-pricing models discussed above a duopoly game of this form is usually reached in the final period. There it is typically assumed (for simplicity) that at that stage the uninformed firm "learns the other's costs" and that the complete information Cournot game then ensues. A more natural formulation

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<sup>3</sup>For a model with signaling between the incumbent firms where there is a continuum of types see Mailath (1984). Parsons (1985) develops a supergame-theoretic model in which there is incomplete information of the kind discussed here. He also develops a two-period model that is similar to the model developed here. However, he restricts attention to separating equilibria and does not derive the welfare results that are essential for the development of this model.



involves the firms' playing the incomplete information game studied here. In the incomplete information game the rival assesses some probability,  $p$ , that it is facing the low-cost predator. This probability will incorporate anything it may have learned about the predator's costs in the course of the first two stages of the game. The firms simultaneously choose outputs given the rivals beliefs,  $p$ . A number of results are readily established. Among the more important are that the profits of both types of the predator firm are increasing in  $p$  while they are strictly decreasing in  $p$  for the rival.

The intuition underlying this is that, ceteris paribus, the low-cost firm produces more than the high-cost firm. Thus, if it believes that it is facing a low-cost firm, the rival will produce less than it otherwise would, regardless of the latter's actual costs, thereby increasing the profits of the predator firm. On the other hand, if the predator knows that the rival is going to curtail its output (because it believes it is facing a low-cost firm) the predator will expand its output (again regardless of its actual costs), thus reducing the profits of the rival.

Now consider the bargaining negotiations that precede this Cournot game. A takeover is less valuable to the predator, and more valuable to the rival, the higher is  $p$ . It thus seems quite plausible that the terms on which the merger are negotiated should be more favorable to the predator, and less favorable to the rival, the higher is  $p$ . We examine this effect within a particular bargaining framework. While there has been a great deal of recent work on bargaining under incomplete information (see, for example, Cramton (1984), Sobel and Takahashi (1983) and Chatterjee and Samuelson (1983)), the framework analyzed here suggests a model of the kind examined by Fudenberg and Tirole (1983). Since we are thinking of the predator as being the potential acquirer, it is natural to examine a situation in which it makes a

take-it-or-leave-it offer to the rival. If the rival accepts the offer, the predator attains a monopoly position whereas the Cournot game ensues if the offer is rejected.

Notice, however, that this bargaining game differs from the standard ones in some important ways. First, the values of reaching agreement to the firms are not independent of each other but instead depend on the costs of both firms. Second, the value of the game if agreement is not reached may depend on the way in which negotiations are conducted. To the extent that the predator's offer reveals information about its type and causes the rival to update its prior, it will also change the value of the Cournot game that ensues if the offer is rejected!

We show that the basic structure of the Fudenberg and Tirole analysis carries through to the case of dependent values. The multiplicity of equilibria that are found there occur here too and are characterized. Furthermore, under a plausible restriction on the rival's beliefs, the outcome of the merger negotiations is monotone in  $p$  as suggested above.

There are thus two reasons why the predator has an incentive to convince the rival that its costs are low (whether they are actually low or not). First, by doing so, the predator will be placed in a stronger negotiating position at the bargaining stage, and, second, if negotiations failed it would be viewed as being a tougher opponent in the post-negotiation Cournot game. The first stage examines the possibility of convincing the rival that its costs are low through a predatory expansion of output.

As in the final stage, the firms are assumed to simultaneously choose outputs. We find that there are two classes of predatory equilibria. In the first both types of predator choose identical outputs ("pooling"). Here the high cost predator produces more than it otherwise would in order not to

reveal that it is the high cost type i.e. it masquerades as the low-cost firm. Salop and Shapiro (1981) refer to this as "bluffing" predation. Scharfstein (1984) analyzes optimal penalties for predation of this kind. In the second class of equilibria the low cost type of predator produces a high enough output that the high cost type finds mimicing unprofitable ("separating").

This model is thus the predation analog of the Milgrom-Roberts limit-pricing model and exhibits similar equilibria. In their model the actions are taken by the incumbent to confuse the potential entrant (in the case of the pooling equilibrium), or to signal low costs to the potential entrant (in the case of the separating equilibrium). The major difference here is that the rival firm has already entered. This change somewhat complicates the analysis however. In this case the amount that the rival produces depends on its expectation as to what the predator of each type will produce, which in turn depends on what the rival produces.

For example, in the separating equilibrium the low cost predator produces more than it otherwise would have so as to distinguish itself as low cost. This induces the rival to produce less than it otherwise would have, which provides an incentive for the high cost predator to produce more than it would have in the absence of the predatory expectations! This occurs even though the latter has no predatory intent. The separating equilibria thus typically involve increased output by both types of predator firm and a lower output by the rival. The result is that while the price is typically lower when the predator is in fact the low cost type, it may actually be higher than it would otherwise be if the predator is the high cost type because the reduction in output by the rival may exceed the increase in production by the high-cost predator.

An important feature of the equilibria is that the leading tests that have been proposed to judge whether pricing is predatory may reach the wrong conclusion from a welfare standpoint.<sup>4</sup> For example, in the separating equilibrium, predation provides the rival with information about the costs of the predator. This information may induce the rival to leave the industry whereas it would have remained in if it had only its prior beliefs about the costs of the predator. If the predator is in fact more efficient than the rival the provision of this information may be socially desirable. Even though a more concentrated industry structure and lower output result, the cost savings that are realized by eliminating the inefficient rival can more than compensate for the loss of consumer surplus. Thus predation may actually be welfare enhancing. However, since the pricing in the first period may well be below marginal cost (and average variable cost) in order to achieve the requisite signaling, the efficient firm would run foul of the Areeda-Turner test. On the other hand, as is discussed in the conclusion, signaling of this kind would not be considered to be predatory by Ordover and Willig (1981). In the case just considered, their test would therefore reach the right conclusion from an economic point of view. However, in those cases where the firm doing the predation is not more efficient than the rival and where the predation is thus welfare reducing, their test errs in the opposite direction: it leaves unpunished welfare reducing predatory acts.

Section II presents the analysis of the incomplete information Cournot game. Section III presents the bargaining model. Section IV examines the predation equilibria. Section V concludes the paper.

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<sup>4</sup>The seminal work is that of Areeda and Turner (1975). Their proposals have been criticized by Scherer (1976). Alternative tests have been proposed by Williamson (1977), Klevorick and Joskow (1979) and Ordover and Willig (1981).

## II. The Cournot Model with One-sided Incomplete Information

We consider a Cournot-style duopoly in which there is incomplete information on one side i.e. in which one of the firms is unsure what the actual costs of its opponent are. We assume that both firms have constant marginal costs and that for the uninformed firm, firm 2, these are  $c_2$  per unit, while for the informed firm these are either  $\underline{c}_1$  ("low") or  $\bar{c}_1$  ("high"). The probability that firm 2 assesses that  $c_1 = \underline{c}_1$  is given by  $p$  and  $p$  is assumed to be common knowledge.

The inverse demand function is assumed to take the form  $P = a - bQ$  where  $Q = q_1 + q_2$  and  $q_i$  is the output of firm  $i$ . We assume that  $c_2 < a$  and  $\bar{c}_1 < a$  so that all firms can produce profitably. Following Cournot the choice of outputs is assumed to be simultaneous. A strategy for firm 1 is therefore a function  $\sigma: \{\underline{c}_1, \bar{c}_1\} \rightarrow [0, \infty)$  i.e.  $\sigma$  stipulates how much to produce for each type of firm 1. A strategy for firm 2 is a function  $\tau: c_2 \rightarrow [0, \infty)$ . A Nash Equilibrium for this game of incomplete information is a pair of mutual best-responses  $(\sigma^*, \tau^*)$ . We denote the output choice of the low and high cost types of firm 1 by  $\bar{q}_1$  and  $\underline{q}_1$  respectively.

The problem facing firm 2 is given by

$$\max_{q_2} p\{(a - b(\underline{q}_1 + q_2))q_2 - c_2 q_2\} + (1-p)\{(a - b(\bar{q}_1 + q_2))q_2 - c_2 q_2\}.$$

The first-order condition is given by:

$$p\{(a - c_2) - b\underline{q}_1 - 2bq_2\} + (1-p)\{(a - c_2) - b\bar{q}_1 - 2bq_2\} = 0$$

which can be rearranged to yield the best-response function for firm 2 of:

$$q_2 = \frac{a - c_2 - b[p\underline{q}_1 + (1-p)\bar{q}_1]}{2b}. \quad (1)$$

This is just the average of the best-response functions to the output of the

low-cost and high-cost types of firm 1 where the former has weight  $p$  and the latter has weight  $(1-p)$ .

The problem facing the low-cost type of firm 1 is given by:

$$\max_{q_1} (a - b(q_1 + q_2))q_1 - c_1 q_1$$

which yields the best-response function

$$q_1 = \frac{a - bq_2 - c_1}{2b}. \quad (2)$$

Similarly, the best-response function for the high-cost type is given by:

$$\bar{q}_1 = \frac{a - bq_2 - \bar{c}_1}{2b}. \quad (3)$$

The Nash Equilibrium solves (1), (2) and (3) simultaneously. The Nash Equilibrium strategies are given by:

$$q_2^* \equiv q_2^* = (a - 2c_2 + pc_1 + (1-p)\bar{c}_1)/3b$$

$$q_1^* = \begin{cases} (a + 2c_2 - c_1(3+p) - (1-p)\bar{c}_1)/6b \equiv \underline{q}_1^*(p), & \text{if } c_1 = c_1 \\ (2a + 2c_2 - pc_1 - (4-p)\bar{c}_1)/6b \equiv \bar{q}_1^*(p), & \text{if } c_1 = \bar{c}_1 \end{cases}$$

The equilibrium price if firm 1 is in fact the low-cost type is given by:

$$P = \frac{1}{6} [2a + 2c_2 + c_1(3-p) - \bar{c}_1(1-p)]$$

while if it is the high-cost type it is:

$$\bar{P} = \frac{1}{6} [2a + 2c_2 - pc_1 + \bar{c}_1(2 + p)].$$

Notice that if  $p=0$  ( $p=1$ ) the standard Cournot equilibrium when firm 1 is the high-cost (low-cost) firm results. If  $0 < p < 1$  then

$$q_2^*(1) < q_2^*(p) < q_2^*(0); \quad \underline{q}_1^*(p) < \underline{q}_1^*(1) \text{ and } \bar{q}_1^*(0) < \bar{q}_1^*(p).$$

The analysis is presented graphically in Figure 1. The best-response functions for both possible types of firm 1 are presented as is the best-

## -FIGURE 1-

response function for firm 2. The equilibrium outcome is  $\underline{N}$  when  $p=1$  and  $\bar{N}$  when  $p=0$ . If firm 1 is in fact the low-cost firm the equilibrium outcome varies from  $\underline{N}$  to A as  $p$  goes from 1 to 0. Similarly if firm 1 is the high-cost firm the equilibrium outcome varies from  $\bar{N}$  to B as  $p$  goes from 0 to 1. The expected outcome when firm 2 assigns probability  $p$  to the event that firm 1 is the low-cost firm varies continuously from  $\bar{N}$  to  $\underline{N}$  as  $p$  goes from 0 to 1. The isoprofit curves indicate the following:

Proposition 1: Both types of the informed firm are more profitable the higher is  $p$ .

Notice that in equilibrium firm 2 produces its best-response to the output  $(1-p')\bar{q}_1^*(p') + p'q_1^*(p')$ . This is lower than it's response would have been if it knew it was facing type  $\bar{c}_1$  with certainty and higher than if it was certain it was facing  $c_1$ . The following are easily established from firm 2's isoprofit curves:

Proposition 2: If firm 2 is in fact facing a high-cost opponent its profitability is strictly decreasing in  $p$ .

Proposition 3: If firm 2 is in fact facing a low-cost opponent its profitability is typically initially increasing in  $p$  and then decreasing in  $p$ . (The switching point is depicted as C in Figure 1).

The intuition underlying Proposition 3 is the following: If firm 2 is in fact facing a low-cost opponent and this is common knowledge, firm 1 will correctly anticipate that firm 2 will produce a relatively low output. If,

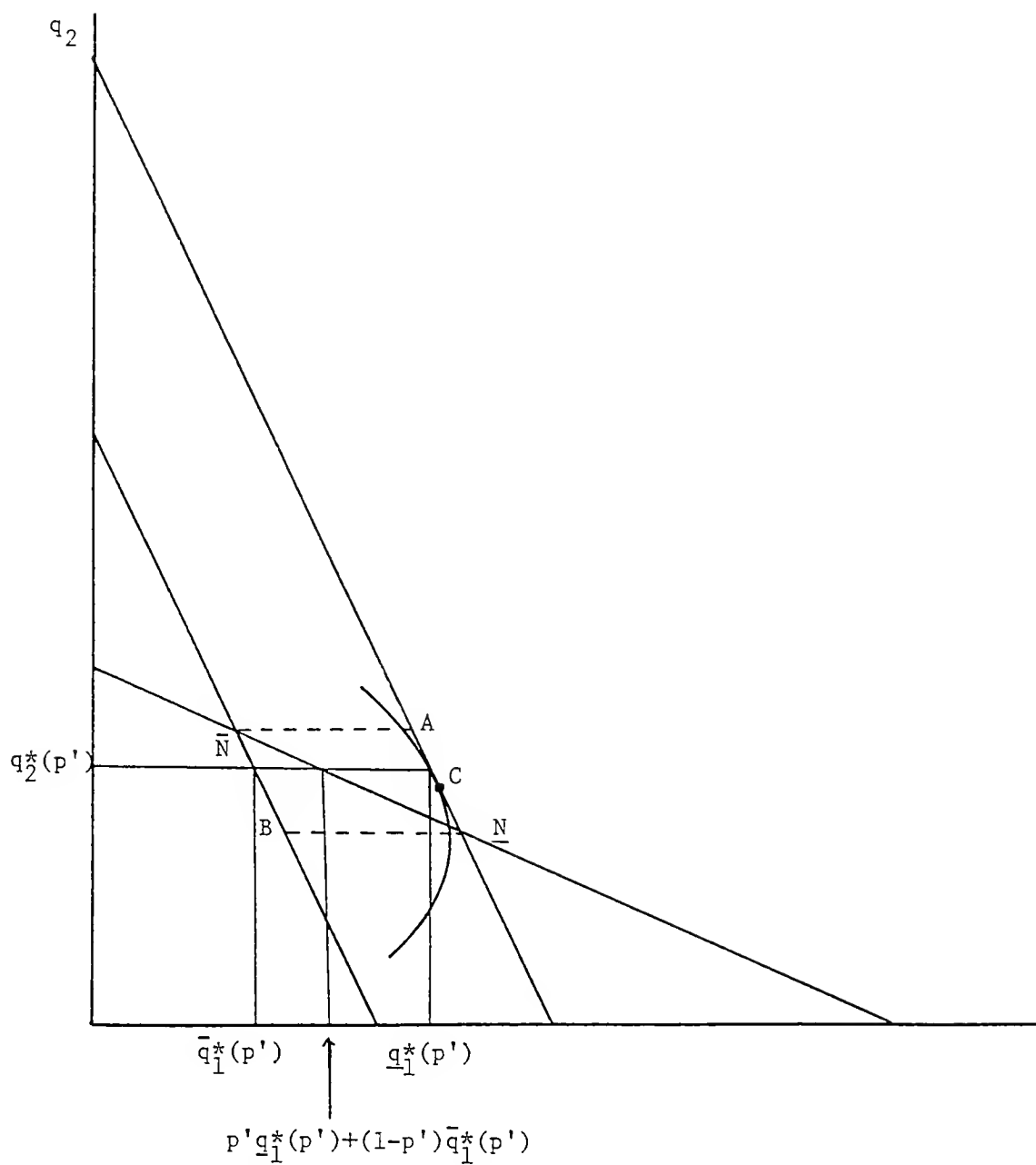


Figure 1: Best-Response Functions and Equilibrium Outputs (When the Prior is  $p'$ )



however, firm 2 strongly believes it is facing a high-cost opponent, it will incorrectly produce too high an output, anticipating a much lower output from its rival than it will in fact produce. Its incorrect beliefs result here in reduced profitability. On the other hand if it is fairly confident it is facing a low-cost opponent but is not certain that it is, its uncertainty induces firm 1 to restrict its own output because it believes firm 2 will produce more than its Nash quantity (in case it in fact is facing the high-cost firm 1). This reduction in output by firm 1 in turn leads to higher profitability for firm 2 (locally).

The expected profit of firm 2 is of particular interest in the next section. We show the following:

Proposition 4: The expected profit of firm 2 is strictly decreasing and strictly concave in  $p$ .

Proof: Denote the expected profit of firm 2 by  $\Pi^2(p)$ . Then

$$\begin{aligned}\Pi^2(p) &= p(\underline{P} - c_2)q_2^* + (1-p)(\bar{P} - c_2)q_2^* \\ &= q_2^*(p\underline{P} + (1-p)\bar{P} - c_2)\end{aligned}$$

Substituting for  $\underline{P}$  and  $\bar{P}$  and simplifying yields:

$$\begin{aligned}\Pi^2(p) &= q_2^* \frac{1}{3} (a - 2c_2 + p\underline{c}_1 + (1-p)\bar{c}_1) \\ &= \frac{1}{9p} (a - 2c_2 + p\underline{c}_1 + (1-p)\bar{c}_1)^2.\end{aligned}$$

$$\frac{d\Pi^2(p)}{dp} = \frac{2}{9b} (a - 2c_2 + p\underline{c}_1 + (1-p)\bar{c}_1)(\underline{c}_1 - \bar{c}_1) = \frac{2}{3} q_2^* (\underline{c}_1 - \bar{c}_1) < 0$$

since  $q_2^* > 0$  and  $\underline{c}_1 < \bar{c}_1$ .

$$\frac{d^2\Pi^2(p)}{dp^2} = \frac{2(\underline{c}_1 - \bar{c}_1)(\underline{c}_1 - \bar{c}_1)}{9b} = \frac{2}{9b} (\underline{c}_1 - \bar{c}_1)^2 > 0. \quad \text{Q.E.D.}$$

In evaluating the welfare consequences of the firms' behavior it is

usual to distinguish between ex ante efficiency and ex post efficiency (See Holmstrom & Myerson (1983) for a discussion. Ex ante efficiency considers the expected outcome given the uncertainty that firm 2 faces i.e. it measures the welfare "before" the actual type of firm 1 is known. By contrast, ex post efficiency measures the welfare given the actual type of firm 1. Ex ante efficiency is the relevant concept for an uninformed social planner or one who is formulating general policy rules that must apply to any ex post situation. Ex post efficiency is applicable if the social planner can tailor policy to the actual situation.

For consumer surplus we have:

Proposition 5: Ex ante consumer surplus is strictly increasing in  $p$ , while ex post consumer surplus is strictly decreasing in  $p$ .

Proof: Consumer surplus is strictly increasing in total output. Consider first the ex post outcomes. For each type of firm 1 these vary along the corresponding best-response function for firm 1. From (2) and (3) total output  $q_1 + q_2$  is given by  $(a - 2bq_2 - c_1)/2b + q_2 = (a - c_1)/2b + q_2/2$  which is clearly increasing in  $q_2$ . Thus total output decreases from  $A$  to  $\underline{N}$  and from  $\bar{N}$  to  $B$ . A similar argument (using (1)) shows that total output increases from  $\bar{N}$  to  $\underline{N}$ . Q.E.D.

This result does not rely heavily on the linearity of demand. For example, Kreps and Scheinkman (1984) have shown that for concave demand the best-response functions have slope less than  $-1$ . The proof of Proposition 5 clearly goes through in that case.

The overall welfare effects of changes in  $p$  are ambiguous. This is because in addition to changes in total output, the distribution of output between the firms also changes as  $p$  changes. Thus, for example, in the ex

post case, although an increase in  $p$  leads to higher prices it also leads to more production being carried out by firm 1 and less by firm 2. If firm 1 is sufficiently more efficient than firm 2 total social welfare may increase.

Thus we have:

Proposition 6: Ex post social welfare is decreasing in  $p$  if and only if:

$$\underline{P} < 2c_2 - \underline{c}_1, \text{ if firm 1 is the low-cost type}$$

$$\text{or } \bar{P} < 2c_2 - \bar{c}_1, \text{ if firm 1 is the high-cost type.}$$

A sufficient condition for welfare to be decreasing in  $p$  is  $\underline{c}_1 > c_2$  or  $\bar{c}_1 > c_2$  respectively.

Proof: Let welfare in the case where firm 1 is the high-cost type be  $\bar{W}$ .

Then

$$\begin{aligned} \bar{W} &= \frac{1}{2} (a - \bar{P})(\bar{q}_1^* + q_2^*) + \bar{q}_1^* (\bar{P} - \bar{c}_1) + q_2^* (\bar{P} - c_2) \\ &= \frac{1}{2} (a + \bar{P})(\bar{q}_1^* + q_2^*) - \bar{q}_1^* \bar{c}_1 - q_2^* c_2. \end{aligned}$$

$$\text{But } \bar{P} = a - b(\bar{q}_1^* + q_2^*)$$

$$\text{or } \bar{q}_1^* + q_2^* = (a - \bar{P})/b$$

$$\text{Therefore, } \bar{W} = \frac{1}{2b} (a^2 - \bar{P}^2) - \bar{q}_1^* \bar{c}_1 - q_2^* c_2$$

$$\text{Therefore } \frac{d\bar{W}}{dp} = \frac{1}{6b} (\bar{c}_1 - \underline{c}_1) [-\bar{P} - \bar{c}_1 + 2c_2]$$

which has the sign of  $-\bar{P} - \bar{c}_1 + 2c_2$  since  $\bar{c}_1 > \underline{c}_1$  by assumption. This establishes the first part of the result.

Substituting for  $\bar{P}$  and rearranging yields:

$$-\bar{P} - \bar{c}_1 + 2c_2 = 2a + 8\bar{c}_1 + p(\bar{c}_1 - \underline{c}_1) - 10c_2.$$

Since  $\bar{c}_1 > \underline{c}_1$  and  $a > c_2$  this expression is positive if  $\bar{c}_1 > c_2$ . The

analysis for the low-cost type is similar and is omitted.

Q.E.D.

The intuition underlying the inequality  $\underline{P} < 2c_2 - c_1$  is the following: If  $p$  increases sufficiently so that total output in the industry decreases by 1 unit there are two effects. Firstly, the value of goods produced to society decreases by the valuation of the marginal consumer,  $\underline{P}$ . In addition, when output is decreased by 1 unit along firm 1's best-response function, firm 1's output increases by 1 unit while firm 2's output decreases by 2 units. The net change in the valuation of resources used is  $c_1 - 2c_2$ . Welfare is improved if the reduction in benefits is outweighed by the reduction in costs i.e. if  $\underline{P}_1 < 2c_2 - c_1$ .

The ex ante case is a little more complicated. As  $p$  changes, not only is there the corresponding change in welfare along each possible best-response function of firm 1, but there is also a change in the relative likelihoods of the ex post equilibria. As proposition 6 shows, ex post welfare is unambiguously higher in the case where firm 1 has the low cost structure. Thus, the increase in the relative likelihood of the low-cost ex-post situation as  $p$  increases, raises welfare. Furthermore, if the weighted average of the possible costs of firm 1 is "low enough" average welfare across the two ex post equilibria will also increase (Proposition 8). in that case ex ante welfare will be increasing in  $p$ .

Proposition 7:  $\underline{W} > \bar{W}$ .

Proof: Consider first the additional units produced in the low cost case that are not produced in the high cost case (i.e. the extra sales resulting from the decrease in price from  $\bar{P}$  to  $\underline{P}$ ). Since  $\underline{P} > c_1$ , these goods increase social welfare. Moreover, the goods that are produced regardless of the cost structure are produced at lower cost by the low-cost firm. Thus,  $\underline{W} > \bar{W}$ . Q.E.D.

Proposition 8: Ex ante welfare is increasing in  $p$  if and only if

$$5c_2 > a + 4 [(1-p) \bar{c}_1 + pc_1].$$

Proof: Ex ante welfare  $\equiv W = (1-p)\bar{W} + p\underline{W}$ .

$$\begin{aligned} \text{Therefore } \frac{dW}{dp} &= (1-p) \frac{d\bar{W}}{dp} + p \frac{d\underline{W}}{dp} + (\underline{W} - \bar{W}) \\ &= \frac{1}{6b} (\bar{c}_1 - c_1) \{ (1-p)(-\bar{P} - \bar{c}_1 + 2c_2) + p(-\underline{P} - c_1 + 2c_2) \}. \end{aligned}$$

Since  $\bar{c}_1 > c_1$  and  $\underline{W} > \bar{W}$  (by Proposition 6),

$$\frac{dW}{dp} > 0 \text{ iff } \{ (1-p)(-\bar{P} - \bar{c}_1 + 2c_2) + p(-\underline{P} - c_1 + 2c_2) \} > 0.$$

Substituting for  $\bar{P}$  and  $\underline{P}$  and rearranging yields:

$$\{ \cdot \} > 0 \text{ iff } 5c_2 > a + 4 [(1-p)\bar{c}_1 + pc_1]. \quad \text{Q.E.D.}$$

In the above proof the term  $(\underline{W} - \bar{W})$  is the increase in welfare that results from the increased likelihood of the low-cost equilibrium. The term  $(\bar{c}_1 - c_1) \{ \cdot \} / 6b$  represents the average change in ex post welfare as  $p$  changes. If  $c_2$  is sufficiently large relative to the average cost of firm 1 then average ex post welfare will be increasing in  $p$ . In that event both terms, and hence ex ante welfare itself, are increasing in  $p$ .

It is also interesting to note the effect of incomplete information on firm 1 if it is a Stackelberg leader. In that case firm 2 responds to the actual output of firm 1 as its best-response function  $q_2^*$  dictates. Firm 1 accordingly selects its Stackelberg outcome as shown in Figure 2. The resulting outcomes are  $\bar{S}^1$  and  $\underline{S}^1$  if firm 1 is the high-cost and low-cost type respectively. If  $p$  is sufficiently high, the outcome for the high-cost type

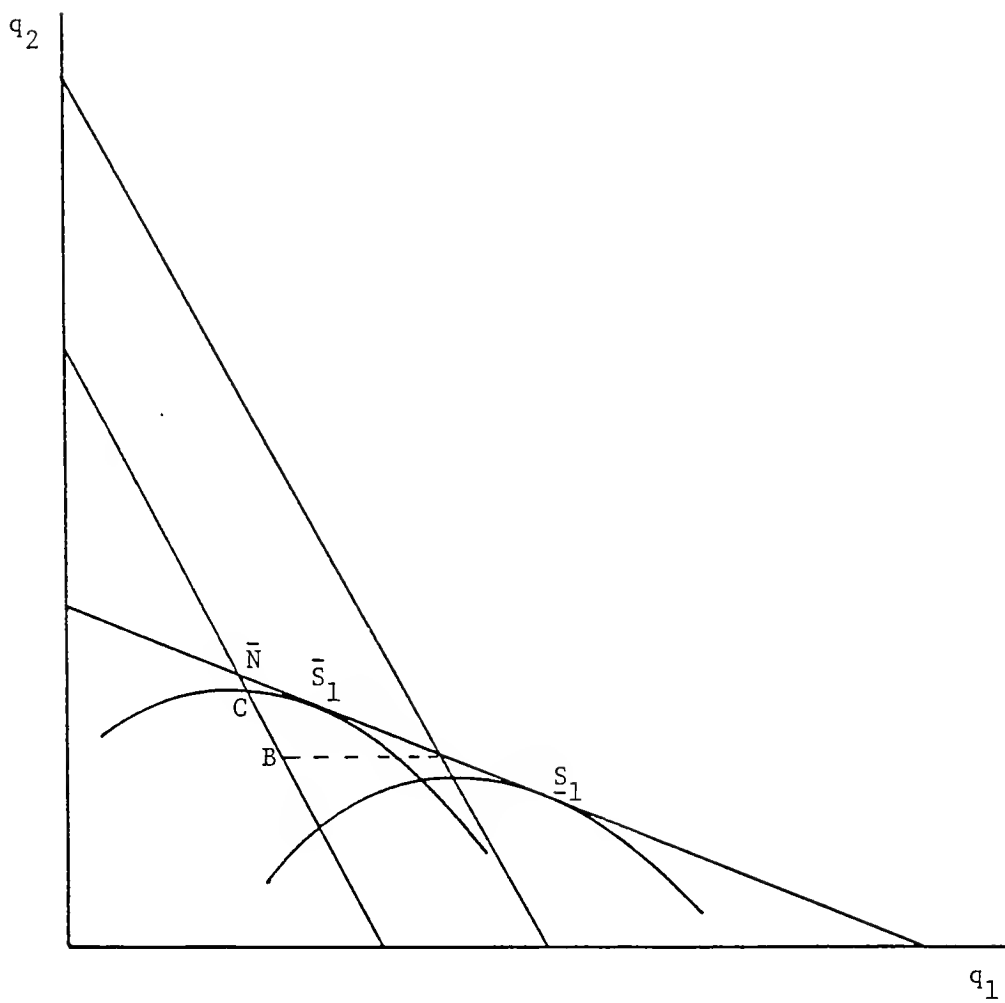


Figure 2: The Stackelberg Outcomes

of firm 1 is on the line segment CB. In that case the high-cost type prefers the Cournot outcome to its Stackelberg leadership outcome. This arises because in the simultaneous move game, the incompleteness of information leads firm 2 to restrict its output (for fear that it is facing the low-cost type). When firm 1 moves first it effectively loses its anonymity and hence the value to it of the incomplete information.

### III. Merger Negotiations with One-Sided Incomplete Information

We now examine the situation before the Cournot game in the previous section is played. Both firms are aware that there may be gains from a buyout of one of the firms by the other. Furthermore they both understand the nature of the incomplete information Cournot game that will ensue if a buyout is not accomplished. In this section we examine the nature of the bargaining problem that the firms face. Of particular interest is the effect of firm 2's prior probability assessment that it is facing a low-cost firm on the outcome of the negotiations.

We begin by deriving the value to each of the firms of achieving a merger. Since we think of firm 1 as the potential acquirer we consider a buyout of firm 2 by firm 1. In order to be able to utilize the apparatus of the previous section we analyze the case where  $c_2 > \bar{c}_1$  so that the acquiring firm continues to use its own technology after the buyout.

In the previous section we showed that the profitability of the Cournot game to player 2 was decreasing and concave in  $p$ . We also showed that the profitability of the Cournot game was strictly increasing in  $p$  for both types of firm 1. Once the buyout has occurred firm 1 will be able to achieve monopoly profits. Since these are independent of  $p$  the value of the buyout is also decreasing in  $p$  for both types of firm 1. However, we also need to

know whether the merger is more or less valuable to the high or low cost type and how this varies with  $p$ .

Let  $\bar{V}(p)$  and  $\underline{V}(p)$  denote the value of a buyout to the high and low cost firm respectively. If we let  $\bar{\Pi}^C(p)$  denote the Cournot profits (characterized in the previous section) to the high-cost type of firm 1 and let  $\bar{\Pi}^M$  denote the monopoly profits to the high-cost type of firm 1, then  $\bar{V}(p) \equiv \bar{\Pi}^M - \bar{\Pi}^C(p)$ .

The following proposition helps to characterize the possible values of a buyout to firm 1:

Proposition 9: (i)  $\underline{V}(0) > \bar{V}(0)$  if and only if  $a > 2c_2 - \bar{c}_1$ , (ii)  $\underline{V}(1) > \bar{V}(1)$  if and only if  $a > 2c_2 - \underline{c}_1$ , (iii)  $\frac{\partial \bar{V}(p)}{\partial p} > \frac{\partial \underline{V}(p)}{\partial p}$  and, (iv)  $\underline{V}(p)$  and  $\bar{V}(p)$  are strictly concave in  $p$ .

Proof:

$$(i) \bar{V}(p) = \bar{\Pi}^M - \bar{\Pi}^C(p)$$

$$\begin{aligned} &= \frac{(a - \bar{c}_1)^2}{4b} - q_1^* (\bar{p} - \underline{c}_1) \\ &= \frac{(a - \bar{c}_1)^2}{4b} - \frac{1}{36b} (2a + 2c_2 - p\underline{c}_1 + \bar{c}_1(2 + p) - 6\bar{c}_1)(2a + 2c_2 - \bar{p}\bar{c}_1 - (4-p)\bar{c}_1). \end{aligned} \quad (4)$$

$$\underline{V}(p) = \frac{(a - \underline{c}_1)^2}{4b} - \frac{1}{36b} (2a + 2c_2 - \underline{c}_1(3-p) - \bar{c}_1(1-p) - 6\underline{c}_1)(2a + 2c_2 - \underline{c}_1(3+p) - (1-p)\bar{c}_1). \quad (5)$$

$$\text{Therefore } \bar{V}(0) = \frac{(a - \bar{c}_1)^2}{4b} - \frac{1}{36b} (2a + 2c_2 - 4\underline{c}_1)^2$$

Letting  $K = 2a + 2c_2 - \bar{c}_1$ , we have

$$\begin{aligned} \underline{V}(0) - \bar{V}(0) &= \frac{1}{36b} [9(a - \underline{c}_1)^2 - 9(a - \bar{c})^2 - (K - 3\underline{c}_1)^2 + (K - 3\bar{c})^2] \\ &= \frac{1}{36b} [18a - 6K](\bar{c}_1 - \underline{c}_1) \\ &> 0 \text{ iff } 3a - K > 0 \end{aligned}$$



$$\text{iff } a > 2c_2 - \bar{c}_1.$$

(ii) The proof is similar to (i) and is omitted.

$$\begin{aligned} \text{(iii)} \quad \frac{\partial \bar{V}(p)}{\partial p} - \frac{\partial V(p)}{\partial p} &= \frac{\partial \bar{\Pi}^c}{\partial p} - \frac{\partial \bar{\Pi}^c}{\partial p} \\ &= (\underline{p} - \underline{c}_1) \frac{\partial q_1^*}{\partial p} + q_1^* \frac{\partial \underline{p}}{\partial p} - (\bar{p} - \bar{c}_1) \frac{\partial \bar{q}_1}{\partial p} - \bar{q}_1^* \frac{\partial \bar{p}}{\partial p}. \end{aligned}$$

$$\text{But } \frac{\partial q_1^*}{\partial p} = \frac{\partial \bar{q}_1^*}{\partial p} = \frac{1}{6b} (\bar{c}_1 - \underline{c}_1) \text{ and } \frac{\partial \underline{p}}{\partial p} = \frac{\partial \bar{p}}{\partial p} = \frac{1}{6} (\bar{c}_1 - \underline{c}_1).$$

$$\begin{aligned} \text{Therefore } \frac{\partial \bar{V}(p)}{\partial p} - \frac{\partial V(p)}{\partial p} &= \frac{1}{6b} (\bar{c}_1 - \underline{c}_1) [\underline{p} - \underline{c}_1 - \bar{p} + \bar{c}_1 b q_1^* - b q_1^*] \\ &= \frac{1}{6b} (\bar{c}_1 - \underline{c}_1) [a - b q_1^* - b q_2^* - a + b \bar{q}_1^* + b q_2^* + b q_1^* - b q_1^* - \underline{c}_1 + \bar{c}_1] \\ &= \frac{1}{6b} (\bar{c}_1 - \underline{c}_1)^2 > 0 \text{ as required.} \end{aligned}$$

$$\begin{aligned} \text{(iv)} \quad \frac{\partial \bar{V}(p)}{\partial p} &= -(\bar{p} - \bar{c}_1) \frac{\partial \bar{q}_1^*}{\partial p} + \bar{q}_1^* \frac{\partial \bar{p}}{\partial p} \\ &= -(\bar{p} - \bar{c}_1) \frac{1}{6b} (\bar{c}_1 - \underline{c}_1) + q_1^* \frac{1}{6} (\bar{c}_1 - \underline{c}_1) \\ &= \frac{-1}{6b} (\bar{c}_1 - \underline{c}_1) [\bar{p} - \bar{c}_1 + b \bar{q}_1^*] \\ &= \frac{-1}{6b} (\bar{c}_1 - \underline{c}_1) [a - b q_2^* - \bar{c}_1] \end{aligned}$$

$$\begin{aligned} \text{Therefore } \frac{\partial^2 \bar{V}(p)}{\partial p^2} &= \frac{-1}{6b} (\bar{c}_1 - \underline{c}_1) (-b) \frac{\partial q_2^*}{\partial p} \\ &= + \frac{1}{6} (\bar{c}_1 - \underline{c}_1) \frac{1}{2b} (-\bar{c}_1 + \underline{c}_1) \\ &= \frac{-1}{18b} (\bar{c}_1 - \underline{c}_1)^2 < 0. \end{aligned}$$

Q.E.D

There are therefore three possible configurations. These are illustrated in Figure 3 where it is also assumed (without loss of generality) that  $\Pi^2(1) > 0$  and  $\Pi^2(0) > 0$ .

## -FIGURE 3-

In all three cases the value of a buyout is decreasing in  $p$  for both types of firm 1 and the value of the Cournot game is decreasing in  $p$  for firm 2. The merger may be more or less valuable to the high-cost type than the low-cost type. For example if  $c_1$  is very low in comparison to  $\bar{c}_1$ , the low-cost type's profits in the Cournot game are relatively high while the high-cost type may have a lot to gain from merger. Notice also that if firm 2 would make losses in the complete information game against the low-cost type of firm 1 ( $\Pi^2(1) < 0$ ), then it would leave the industry in preference to playing the Cournot game if it is sufficiently confident that it is facing a low-cost opponent. This could occur if in addition to its variable costs  $c_2$ , it also had to incur some fixed costs in order to play the Cournot game.

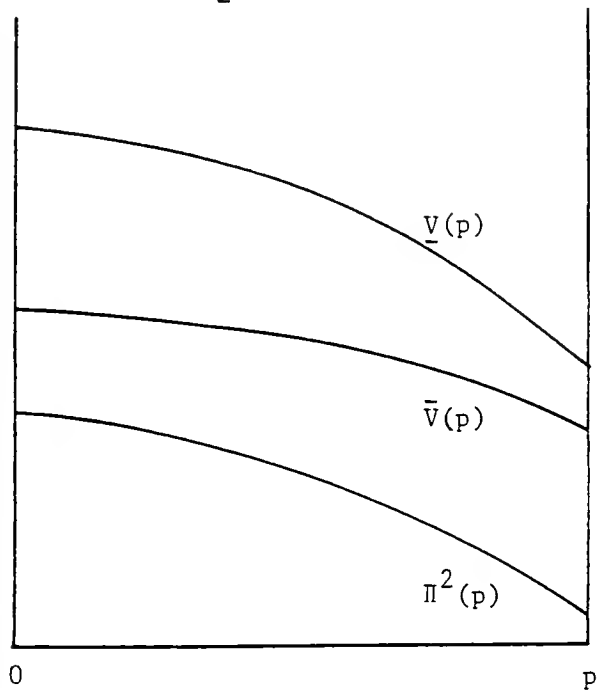
It is quite compelling that the outcome of the merger negotiations should result in a smaller benefit to firm 2, the higher is  $p$ . This is because firm 1's position is strengthened in the sense that it will have higher profits in the ex post Cournot game, while exactly the reverse is true for firm 2.

We examine this effect within the framework of the Fudenberg and Tirole (1983) model. Although we restrict attention to a single offer by firm 1, the signalling issues that arise in their model arise here too. This is because to the extent that firm 1's offer reveals information about its type and causes firm 2 to update its prior, it will also change the value of the Cournot game that ensues if the offer is rejected.

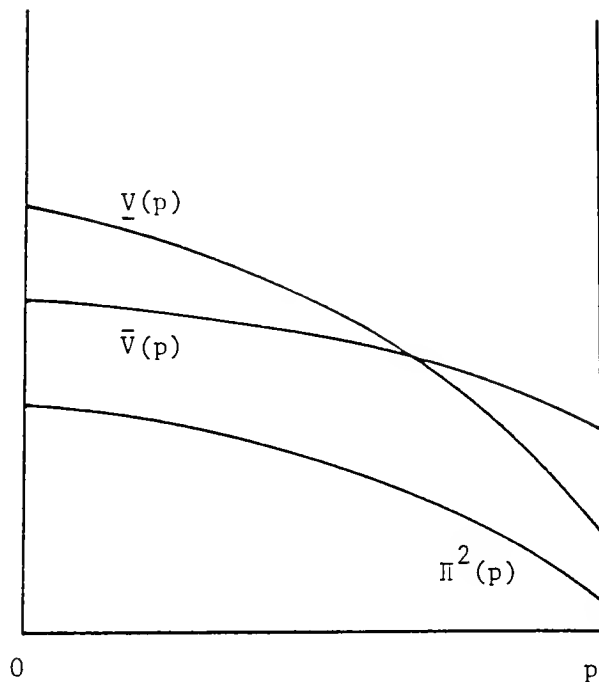
We carry out the analysis for the case where  $\underline{V}(p) > \bar{V}(p)$  for all  $p$  (case (a) above). The analysis is similar for the other cases. Notice firstly that firm 2 never accepts an offer below  $\max \{0, \Pi_2(p)\}$ . The only possible reason

Figure 3: The Value of Merger to Firm 1 and of the Cournot Game to Firm 2

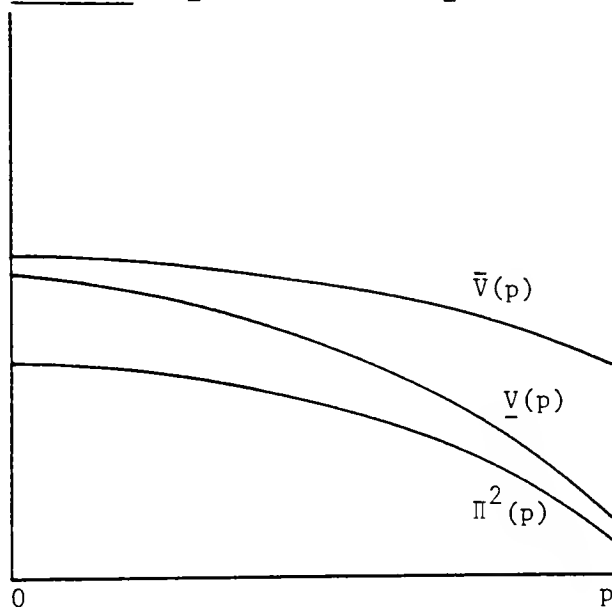
Case (a):  $\underline{V}(0) > \bar{V}(0)$   
and  $\underline{V}(1) > \bar{V}(1)$



Case (b):  $\underline{V}(0) > \bar{V}(0)$  and  
 $\underline{V}(1) < \bar{V}(1)$



Case (c):  $\underline{V}(0) < \bar{V}(0)$  and  $\underline{V}(1) < \bar{V}(1)$



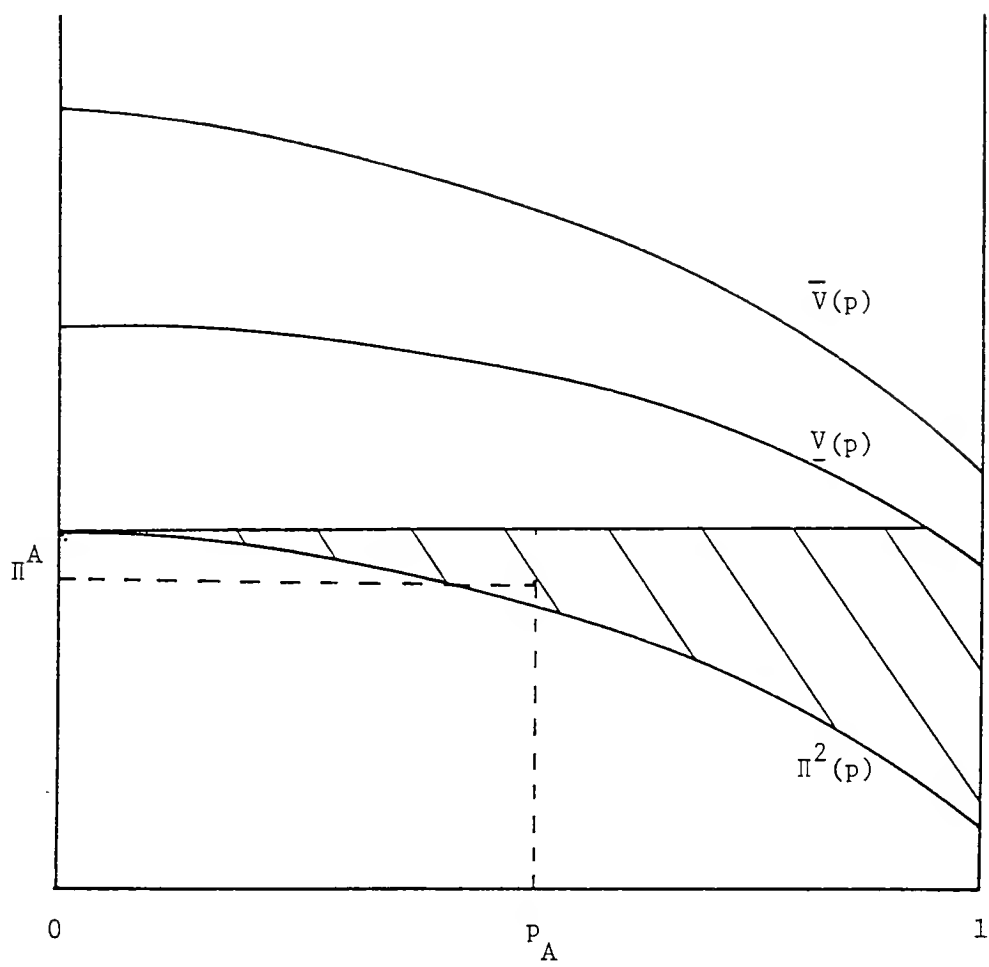
for doing so would be if an offer below that level led it to believe that it was facing the low cost type of firm 1. But in that case the high cost type would make the same offer. Thus firm 2's beliefs would not be justified. On the other hand firm 1 will never make an offer above  $\Pi^2(0)$  which is the most that firm 2 expects to receive in the incomplete information game. This reduces the set of possible equilibrium outcomes to the shaded area in Figure 4 (for the case where  $\Pi^2(0) > 0$ ). Any outcome in the shaded area is sustainable as an equilibrium.

Suppose that firm 2 enters the bargaining with the prior  $p_A$  and consider the outcome A. Outcome A is sustainable as an equilibrium as follows: both types of firm 1 offer  $\Pi^A$  to firm 2. Firm 2 accepts an offer of  $\Pi^A$  or more. However if it observes an offer less than  $\Pi^A$  it believes that firm 1 is the high-cost type. It rejects the offer and enters the ensuing Cournot game with posterior beliefs  $p=0$ .

It is straightforward to see that both types of firm 1 are behaving optimally given how they expect firm 2 to behave. But what of firm 2's behavior? Firm 2's beliefs are extremely prejudicial against the high cost type. It believes that only a high cost type would make an offer below A even though there is nothing that is intrinsically more costly to such an offer by a low type.

Consider what happens if we exclude such prejudicial beliefs i.e. when firm 2 does not change its beliefs when it observes an offer that is equally costly to both types of firm 1. In that case the unique equilibrium for any given level of  $p$  is  $\Pi^2(p)$ . When the beliefs are restricted in this way firm 1 knows that no inference about its type will be drawn from the offer itself. In that case (regardless of its true type) it offers to compensate firm 2 for this expected value of the continuation game, i.e.  $\Pi^2(p)$  (or a little more to

Figure 4: Equilibrium at the Bargaining Stage



break firm 2's indifference). Since firm 2 draws no inference from the offer itself it is willing to accept any amount more than  $\Pi^2(p)$ . In this case the bargaining outcome is indeed monotonically decreasing in  $p$ .

To be concrete in what follows we will assume that  $\Pi^2(p)$  is the outcome of the bargaining game. However, all that is required is that the outcome be monotone in  $p$ . As was mentioned above, this is quite plausible given the monotonicity of  $\underline{V}(p)$ ,  $\bar{V}(p)$  and  $\Pi^2(p)$  and does not rely on the bargaining framework and equilibrium selection used above.

#### IV. Predation

We turn now to a discussion of the incentive for predation in the stage preceeding the bargaining negotiations. We assume that firms 1 and 2 are both incumbents in the industry. As in Section II the firms are assumed to simultaneously select their outputs. The analysis differs from that in Section II, however, since the outcome here may affect firm 2's beliefs about the cost structure of firm 1, and thereby the payoffs in later stages. In particular the low cost type has an incentive to distinguish itself from the high cost type since the outcome of the merger negotiations are more favorable to the low cost type. Alternatively, if no merger was anticipated or if it was prohibited by law, the outcome of the second period Cournot is more favorable to firm 1 the lower firm 2 believes its costs to be. Conversely, the high cost type has an incentive to masquerade as the low cost type for the same reasons. As was mentioned in the introduction, it is possible for there to be some equilibria in which the low cost type succeeds in distinguishing itself from the high cost type, and others in which it fails.

These are the standard separating and pooling equilibria that occur in models of incomplete information where signaling is important.

The analysis is more complicated than in the usual models, however. In the standard models the starting point is to establish the action the uninformed player would take absent any signaling considerations. (Elsewhere I have called this the player's "null" act, see Saloner (1982)). In the separating equilibrium the high cost player then uses its null act and the low cost player takes an action that is capable of distinguishing it as the low cost player by virtue of the fact that it would not be mimiced by the high cost player. In this setting, however, the action that is required to distinguish itself depends also on the action of the uninformed player, firm 2, which in turn depends on the action of the high cost type, which in turn depends on the action of firm 2. Thus all three equilibrium actions must be solved for simultaneously. Similar complications apply to the case of pooling equilibria. We examine the separating equilibria first.

#### (i) Separating Equilibrium

There are three equilibrium conditions that must be satisfied, one for each firm. First, given the expected outputs of the high cost and low cost firms,  $\bar{q}_1$  and  $\underline{q}_1$  respectively, firm 2 must produce its best-response. From (1) this is:

$$q_2 = (a - c_2 - b[p^0 \underline{q}_1 + (1 - p^0)\bar{q}_1]) / 2b \quad (6)$$

where, in order to distinguish the firms prior at the beginning of the first period from its posterior at the end of the first period (which we have called  $p$ ), we denote the former by  $p^0$ .

Second, the high cost type of firm 1 must produce its best-response to  $q_2$  (its null act given  $q_2$ ). From (3) this is:

$$\bar{q}_1 = (a - bq_2 - \bar{c}_1)/2b. \quad (7)$$

Finally,  $q_1$  must be such that the high cost type of firm 1 prefers to produce its best-response to  $q_2$  (and thus to be identified as a high cost type) to mimicing  $\bar{q}_1$ . If the high cost type mimics the output of the low cost type it earns  $(a - b(q_1 + q_2))\bar{q}_1 - \bar{c}_1 q_1$  in the first period. Firm 2 then believes it is the low cost type and updates its beliefs to  $p=1$ . Accordingly, using the outcome of the bargaining model in the previous section, the takeover is accomplished at a cost of  $\Pi^2(1)$ . Thereafter the firm earns its monopoly profits of  $\bar{\Pi}^m$ .<sup>5</sup> We assume that the profits for the first period accrue at the end of that period and that the takeover settlement is made immediately thereafter. The second period monopoly profits are assumed to accrue a period later. Thus the former are not discounted and the latter are discounted with a factor of  $\delta$ . Thus, the profits to a high cost firm that mimics a low cost firm are

$$(a - b(q_1 + q_2) - \bar{c}_1)\bar{q}_1 - \Pi^2(1) + \delta\bar{\Pi}^m. \quad (8)$$

On the other hand, if it allows its type to be revealed it must pay the higher amount,  $\Pi^2(0)$ , to accomplish the takeover and it earns:

$$(a - b(\bar{q}_1 + q_2) - \bar{c}_1)\bar{q}_1 - \Pi^2(0) + \delta\bar{\Pi}^m. \quad (9)$$

Combining (8) and (9) for it not to be worthwhile for the high cost type to mimic the low cost type  $q_1$  must be sufficiently large that:

$$(a - b(q_1 + q_2) - \bar{c}_1)q_1 - \Pi^2(1) < (a - b(\bar{q}_1 + q_2) - \bar{c}_1)\bar{q}_1 - \Pi^2(0). \quad (10)$$

Using the stability arguments of Kohlberg and Mertens (1982) as applied

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<sup>5</sup>If the firm produces its monopoly profits after the takeover has been accomplished, as we have assumed, it will reveal its costs to potential entrants. If entry is unimpeded it may prefer to disguise its type post entry by producing the monopoly output of the low cost type. This would not change the basic nature of the analysis.



to signalling games by Kreps (1984), we can replace the inequality in (10) by an equality. The idea is the following. Consider the smallest  $q_1$  for which (10) holds. No rational high cost firm would produce an amount that large (or larger) regardless of the inference that firm 2 might draw from such an action. Accordingly, a rational firm 2 should conclude that such an output must have been produced by a low cost type of firm 1. Therefore, in order to signal its true type, the low cost firm need produce no more than the smallest  $q_1$  for which (10) holds. If we assume, as we will, that the low cost type's null act is less than this minimal level (so that it would be mimiced if it chose its equilibrium output ignoring the signaling implications) then the low cost type would indeed choose the smallest  $q_1$  satisfying (10).

We solve equations (6), (7) and (10) (with equality) simultaneously. Substituting (7) in (6) yields:

$$q_2 = [a(1+p^0) - 2c_2 + \bar{c}_1(1-p^0)] / [b(3+p^0) - 2p^0 q_1 / (3+p^0)]. \quad (11)$$

Substituting (6) and (11) in (10) and solving gives (after some minipulation):

$$q_1^* = \frac{a+c_2-2\bar{c}_1}{3b} + \frac{(3+p^0)}{3b} \sqrt{6R}, \quad (12)$$

where  $R \equiv \delta(\Pi^2(0) - \Pi^2(1))$  is the reward to being preceived as being the low cost type at the bargaining stage and the star denotes an equilibrium level. This has a straightforward interpretation. The first term is simply the high cost firm's standard Cournot output in the complete information game. The second term represents the additional amount that the low cost firm must produce in order to prevent the high cost firm from mimicking it. If there is no reward to being perceived as being the low cost type then the second term

is zero and any amount above the high cost firm's Cournot output will succeed in distinguishing the low cost firm.

The comparative statics on  $q_1$  are intuitive. The higher the reward to being perceived as low cost, i.e. the higher is  $R$ , the more signaling is required and hence the higher is  $q_1^*$ . Holding  $R$  constant,  $q_1^*$  is increasing in  $p^0$ . Because  $q_2$  is decreasing in  $p^0$ , the higher  $p^0$  is the higher the best-response of both types of firm 1 is. Thus absent the signaling consideration firm 1 would produce more when  $p^0$  is high. Accordingly, in order to convincingly signal that it is low cost the low cost firm must also produce more when  $p^0$  is high than when it is low.

From (8)  $q_2^*$  is decreasing in  $q_1^*$  and from (7)  $\bar{q}_1^*$  is decreasing in  $q_2^*$ . Thus  $q_2^*$  is decreasing in  $p^0$  and  $\bar{q}_1^*$  is increasing in  $p^0$ . The interpretation of this is that the higher is  $p^0$  the more predation is required by the low cost firm to convince the rival of its low costs. Since firm 2 anticipates this predatory act (with probability  $p^0$ ) it reduces its output. But this induces the nonpredatory high cost firm to expand as well.

Notice that  $q_1^*$  is independent of  $c_1$ . This is because (12) provides the condition that prevents the high cost type from mimicing the low cost type. This depends on how costly it is for the high cost type to mimic which depends on  $\bar{c}_1$  not  $c_1$ . There is thus no relationship between (12) and the low cost firm's nonpredatory Cournot level of Section II. It is quite possible that the latter is higher than (12) in which case the signaling is accomplished costlessly. It is only where (12) is greater than that, that predation will occur. Notice also that in the event that it is necessary for the low cost firm to exceed its standard Cournot level we must check that it in fact prefers to pay the costs of signaling and thereby to distinguish

itself from the high cost type to playing its best-response to  $q_2^*$  and being believed to be high cost.

For concreteness we plot the equilibrium values for a numerical example in which  $a=10$ ,  $b=1$ ,  $c_2 = \bar{c}_1 = 2$ ,  $\underline{c}_1 = 0.5$  and  $\delta = 1$ .<sup>6</sup> The values of  $\underline{q}_1^*$ ,  $\bar{q}_1^*$  and  $q_2^*$  are plotted in Figure 5 along with the corresponding values for the one-stage game of Section II. The effect of the predation is clear. As discussed above, the predatory action of the low cost firm also affects the action of the high cost firm although the latter is not predatory at all.

#### (ii) Pooling Equilibrium

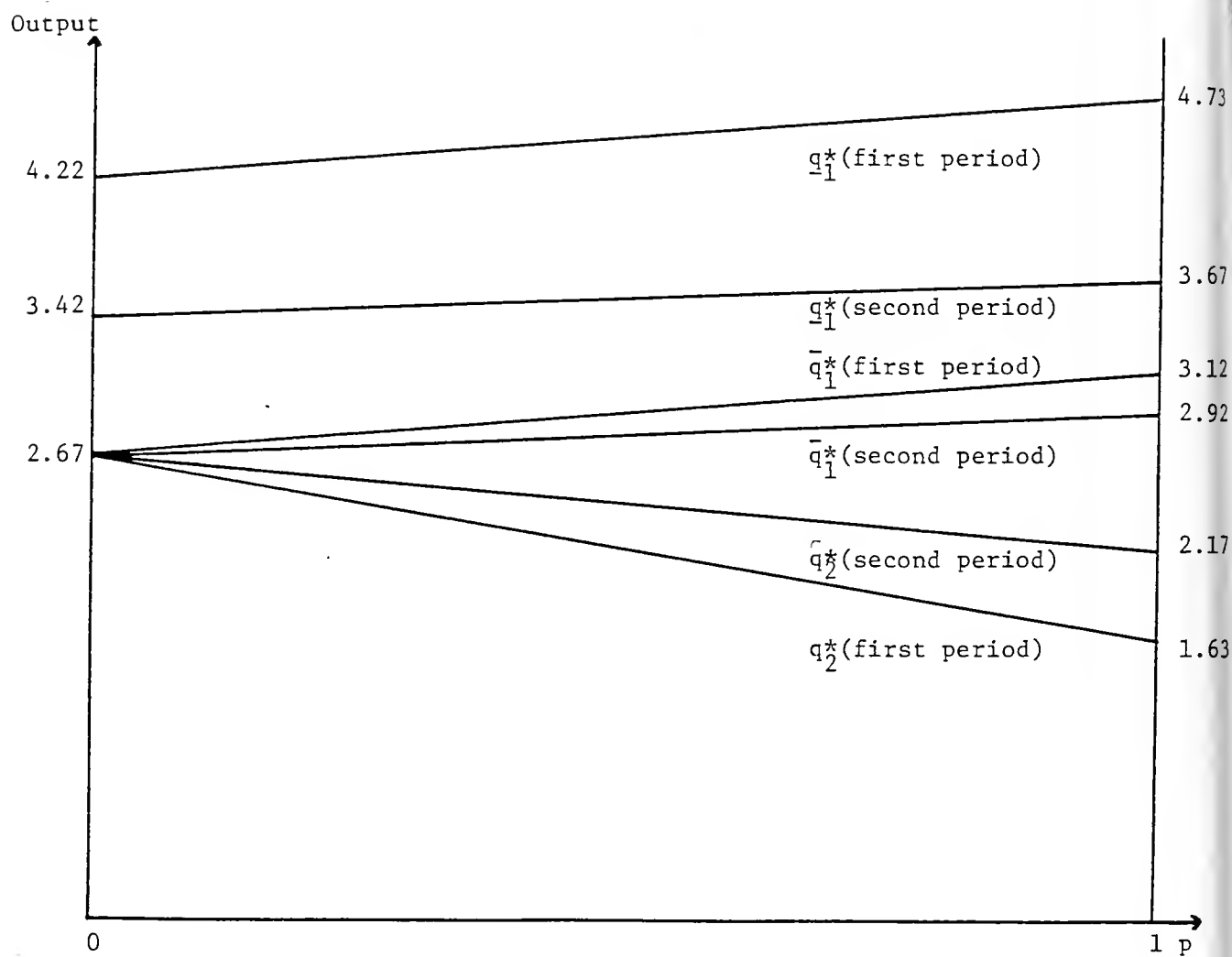
There may also be equilibria in which both types of predator produce the same quantity and in which they are thus not distinguishable in equilibrium. The equilibrium conditions here are much more straightforward. By definition we must have  $\underline{q}_1^* = \bar{q}_1^*$ . There may be multiple equilibria. We focus on the one in which the low cost firm produces its null quantity, i.e. it operates along its own best-response function. Since firm 2 anticipates that  $\underline{q}_1^* = \bar{q}_1^*$  it produces its best-response to  $\underline{q}_1^*$ . Thus it operates along its best-response function. The resulting equilibrium is at the intersection of these best-response functions.

There are two additional equilibrium conditions that must be satisfied. In a pooling equilibrium the rival will not alter its prior after observing the equilibrium outputs. At the negotiation stage, therefore, the acquisition will be made at a cost of  $\Pi^2(p^0)$ . One condition is that the high cost firm must prefer the pooling action and an acquisition price of  $\Pi^2(p^0)$  to producing its null act (thus revealing its type) with the resulting

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<sup>6</sup>These are the same parameter values used by Milgrom and Roberts (1982a).

Figure 5: Equilibrium Outputs in the First (Predatory) and Second (Nonpredatory) Periods



acquisition price of  $\Pi^2(0)$ . The second condition is a little more subtle. From (10) anticipating  $q_2^*$  there is an action that the low cost firm can take that will not be mimiced by the high cost type under any circumstances. Again using Kreps' arguments this should reveal that low cost firm's type. For the equilibrium to hold it must be the case that the low cost firm prefers its pooling action (and an acquisition price of  $\Pi^2(p^0)$ ) to this separating action (and an acquisition price of  $\Pi^2(1)$ ).

We explore these conditions within the context of the above numerical example. The candidate pooling equilibrium has  $q_1^* = 3-2/3 = \bar{q}_1^*$  and  $q_2^* = 2-1/6$ . The first condition reduces to:

$$7.944 - \Pi^2(p^0) > 8.507 - \Pi^2(0)$$

$$\text{or } p^0 > 0.2159.$$

Using (10) it is straightforward to show that, anticipating  $q_2^* = 2-1/6$ ,  $q_1$  would have to be 5.0724 in order for the low cost firm to distinguish itself. The second condition requires that the low cost firm not find it preferable to so distinguish itself. This reduces to

$$\Pi^2(p) < 6.6702$$

$$\text{or } p^0 > 0.168.$$

Thus if  $p^0$  is sufficiently small no pooling equilibrium exists. If  $p^0$  is small the cost to the high cost firm of revealing its type is small. Then the first condition fails. Also, if  $p^0$  is small the low cost firm has a lot to gain by distinguishing itself and the second condition fails.

If firm 2 never believes that  $q_1 < \bar{q}_1$  (which seems plausible) there are no pooling equilibria with  $q_1^* < 3-2/3$ . This follows because  $q_2^*$  must always lie along firm 2's best-response function. However, except at  $q_1^* = 3-2/3$  this requires that the low cost firm 1 produce less than its best-response.

But if firm 2's beliefs are (weakly) monotone as suggested, there is no penalty to the low cost firm of increasing its output up to its best-response. Thus it would deviate.

There may, however, exist equilibria in which  $q_1^* = \bar{q}_1^* > 3-2/3$ . These are sustained by the belief by firm 2 that any lower output by firm 1 would only be produced by the high cost type. As  $q_1^*$  is increased, however, it becomes more and more costly for the high cost firm to mimic the behavior of the low cost firm. As a result the equilibria will exist only for increasingly higher values of  $p^0$ .

## V. Conclusions

Where the rationale for predatory pricing is to convey private information the usual conclusions about predation may be inappropriate. First, even if a merger between the two firms is legal and anticipated, it may be preceded by predation by the acquiring firm. The predation serves to convince the firm to be acquired that the acquirer is "tough" and that the merger is not as valuable to it as might otherwise have been believed. The advantage that the acquirer obtains in its takeover terms may more than compensate it for the signaling costs incurred. In that case McGee's arguments against predation are inappropriate.

The arguments of this paper do not depend on the presence of the merger phase. Absent the merger phase firm 1's profits are nonetheless increasing in  $p$  in the second period. Thus the incentive to convince the rival that it is "tough" remains. Moreover, if the rival must incur additional fixed costs in the second period, it may be possible for firm 1 to drive it out of the market altogether. In particular if these fixed costs are such that the

rival would earn positive profits only against the high cost type, by convincing the rival that its costs are low the predator will drive the rival out of the market.<sup>7</sup> Notice that the difficulty that must usually be dealt with as to why reentry (or de novo entry) does not occur once the price is raised after the rival exits do not arise here. This is because the purpose of the predation is neither to establish a "low" price nor to sap the resources of a particular rival, but rather to establish that the predator's costs are so low that even "peaceful" coexistence is not profitable.

In this model it is not necessary that the predator face the same rival in the two periods. Clearly, since the predatory actions are as effective as signals to potential entrants as to incumbent firms, it is immaterial whether it is the same rival (or market) that the predator will be active in each of the two periods.

Because the predation conveys information and hence serves a potentially useful social function it is quite possible for predation of this kind to be welfare enhancing. In particular, if firm 1 in fact has lower costs than firm 2 but  $p$  is low (so that the rival mistakenly believes that firm 1 has high costs) firm 2 will produce more, and firm 1 less, than they would with complete information. Because of the inefficient production by firm 2, the total firm profits will be much lower than they need be. In these circumstances the total of consumer surplus and profits may be higher under monopoly than in the corresponding Cournot equilibrium. For example, if  $c_2=4$  and  $c_1=0$  the sum of profits and consumer surplus when firm 1 is the

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<sup>7</sup>This outcome can be supported in a separating equilibrium exactly analogous to that of the previous section. The only difference is that the reward to changing the rivals perception (called  $R$  in the previous section) is now given by  $\Pi^M(c_1) - \Pi^C(p)$  where  $p$  is the rivals belief at the beginning of the second stage.

monopolist is 37.5. By contrast, if  $p=0$  the Cournot game of incomplete information yields a sum of consumer surplus and profits of only 36.83. Thus if (i) a takeover is prohibited, (ii) firm 1's "predatory" actions are effectively prevented and (iii) firm 2 remains convinced that firm 1 is the high cost type, welfare as measured by the sum of consumer and producer surplus will be lower in the second period. In addition, welfare will be lower in the first period since firm 1's predatory practices would temporarily lower prices. On the other hand, if a takeover is permitted then the only effect of preventing the first period predation is to improve firm 2's bargaining position (which is a transfer from firm 1 to firm 2) and to raise the first period price. Thus, here too welfare is lower if the predation is prevented.

Although this "predatory" action by firm 1 is welfare enhancing it could run foul of the legal rules that have been proposed for detecting harmful predation by Areeda and Turner (1975). They argue that a firm's prices set below average variable cost should be deemed predatory. However, in order to achieve the requisite signaling the low cost firm in our analysis may well have to produce an output that results in the price being below its average variable costs. This is especially the case if the reward to the signaling is high. This occurs when its costs are in fact much lower than is commonly believed, when the market is growing rapidly, or when it operates in many markets so that the benefits to its signaling will be reaped in other markets as well.

In this respect, the test proposed by Ordover and Willig (1981) is far superior. Their test requires asking whether the firm's action would have been optimal if the rival faced no reentry barriers. If this is answered in the affirmative then the action is deemed not to have been predatory. Since



the rival in the above analysis faces no reentry costs this requirement is trivially satisfied. However, while the Ordover and Willig test is not subject to classifying welfare enhancing signaling actions as predatory ("type II" errors) it is subject to classifying welfare reducing signaling as nonpredatory ("type I" errors). Since the rival faces no reentry costs the exit of the rival in any separating equilibrium of the kind we have analyzed will never be deemed to be predatory. However, in those cases where firm 1 is not much more efficient than the rival, welfare will be reduced by the exit of the rival and consequently the Ordover and Willig test would reach the wrong conclusion.

These tests and others (see also Klevorick and Joskow (1979) and Williamson (1977)) are unlikely to run into difficulty in situations involving rivalries between industry incumbents of long standing, where technological change is slow and where the technology used is fairly standard. In these situations, asymmetric information is likely to be unimportant and hence signaling (of the kind studied here), unlikely to occur. In situations involving new entry or rapid technological change, however, blind application of these tests may lead to inappropriate conclusions.

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